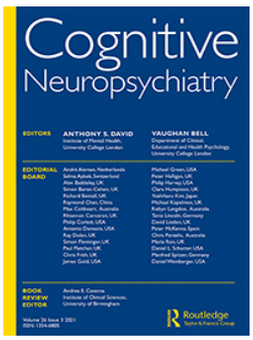

Cognitive Neuropsychiatry

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/pcnp20

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To cite this article: Nathan Caruana & Kiley Seymour (2021) Bottom-up processing of fearful and angry facial expressions is intact in schizophrenia, Cognitive Neuropsychiatry, 26:3, 183-198, DOI: 10.1080/13546805.2021.1902794

To link to this article: https://doi.org/10.1080/13546805.2021.1902794

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COGNITIVE NEUROPSYCHIATRY
2021, VOL. 26, NO. 3, 183–198
https://doi.org/10.1080/13546805.2021.1902794

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Bottom-up processing of fearful and angry facial expressions is intact in schizophrenia

Nathan Caruana[a,b] and Kiley Seymour[c,d,e]

[a]Department of Cognitive Science, Macquarie University, Sydney, Australia; [b]Perception in Action Research Centre, Macquarie University, Sydney, Australia; [c]School of Psychology, Western Sydney University, Sydney, Australia; [d]The MARCS Institute for Brain, Behaviour and Development, Western Sydney University, Sydney, Australia; [e]Max Planck Institute for Biological Cybernetics, Tübingen, Germany

ABSTRACT

Introduction: Judgments of emotion from faces are reportedly impaired in schizophrenia. However, it is unclear whether this is due to a top-down cognitive deficit in *evaluating* sensory information or a fundamental bottom-up perturbation in the early stages of face encoding. This study examined whether deficits in emotion processing reflect imprecision in the initial preconscious registration of emotional face expressions within the visual system.

Methods: Using continuous flash suppression (CFS), we presented participants (18 patients with schizophrenia, 8M/10F; 20 healthy controls, 13M/7F) with fearful and angry faces. Previous CFS research on healthy participants reveals that fearful facial expressions gain privileged access to awareness over angry faces —demonstrating the visual system's ability to discriminate these emotions at a preconscious level. We used this same approach to probe the integrity of early emotion encoding whilst minimising the potential contribution of any top-down cognitive biases on perceptual judgments.

Results: In both groups, fearful faces were perceived faster than angry faces, with no differences observed between patients and controls.

Conclusions: Emotion processing difficulties in schizophrenia are unlikely to reflect an early sensory deficit, but rather a deficit in social cognition that has a top-down impact on the conscious evaluation of facial expressions.

ARTICLE HISTORY
Received 2 July 2020
Accepted 8 March 2021

KEYWORDS
Face processing; emotion; social perception; schizophrenia; continuous flash suppression

Although schizophrenia is an illness typically associated with the presence of positive symptoms such as delusions or hallucinations (American Psychiatric Association, 2013), a growing body of evidence suggests that deficits in social cognition exert considerable impact on daily functioning (Kee et al., 2003; Penn et al., 1996). For instance, patients with schizophrenia experience a range of difficulties with social interactions (e.g. Aghevli et al., 2003; Pinkham & Penn, 2006), leading to disability in societal participation and a reduced quality of life. In particular, higher-order social cognitive difficulties such

CONTACT Nathan Caruana nathan.caruana@mq.edu.au Department of Cognitive Science, Macquarie University, Level 3, 16 University Ave., Sydney, NSW 2109, Australia

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as mental state reasoning and the evaluation of social cues are commonly reported in the literature (Green et al., 2015). In the past decade, however, research has also asked whether the aberrant perceptual processing of social cues might underpin the reported social cognitive deficits in schizophrenia (Caruana, Stein, et al., 2019; Chen et al., 2007; Darke et al., 2013; Doop & Park, 2009; Fletcher & Frith, 2009; Palmer et al., 2018a, 2018b; Seymour et al., 2016; Seymour et al., 2017; Silverstein, 2016; Uhlhaas & Mishara, 2006). Currently, however, there is a dearth of empirical research that has directly tested perceptual sensitivity to social cues in schizophrenia whilst adequately controlling for possible confounding influences of higher-order cognitive deficits on perceptual judgments.

A large body of research on social cognition in schizophrenia consistently reports anomalies in face perception—with differences primarily reported with emotion perception (Billeke & Aboitiz, 2013; Marwick & Hall, 2008). Three recent meta-analyses have estimated large and consistent effect sizes for deficits in facial expression discrimination tasks ($d = -.91$, $d = -.85$, and $g = .89$ respectively; Chan et al., 2010; Kohler et al., 2010; Savla et al., 2013), with the largest impairments seen for negative emotions such as fear and anger (Bediou et al., 2005; Comparelli et al., 2014; Edwards et al., 2001; Kohler et al., 2003, 2010; Mandal et al., 1998). Importantly, these impairments persist over time, even when positive symptoms are controlled pharmacologically, suggesting that they are stable and relatively unaffected by disease state or medication (e.g. Addington & Addington, 1998; Hempel et al., 2010). However, despite the clear evidence for a deficit in emotion judgements and results suggesting a top-down involvement, it remains unknown whether a perturbation of fundamental bottom-up mechanisms (e.g. in the early encoding of face information within the visual system) might also contributes to this.

There are now several streams of evidence suggesting that cognitive biases likely drive impairments in emotional face processing in schizophrenia. First, whilst patients exhibit a tendency to attribute hostility, anger, untrustworthiness and even disgust to ambiguous faces (Habel et al., 2010; Kohler et al., 2003; Pinkham et al., 2011; Premkumar et al., 2008; Weiss et al., 2007), similar biases are also seen when patients read written vignettes of negative social situations with an ambiguous cause (Pinkham et al., 2016). This suggests that not all social attribution biases observed in schizophrenia can be explained by visual social information processing aberrations. Moreover, in recent modelling work, a tendency to categorise faces with direct gaze as angry and faces with averted gaze as fearful can be explained by a decision bias in patients, in contrast to a modulation of perceptual sensitivity seen in healthy controls (Caruana et al., 2020). Specifically, Bayesian model selection suggests that in heathy participants the effect of gaze on emotion categorisation accuracy increases as a function of emotion intensity, whereas in patients the bias exists irrespective of emotion intensity. Further evidence for the role of higher-order cognitive mechanisms comes from studies which demonstrate the effective treatment of social deficits in schizophrenia—including emotion recognition impairments—with cognitive interventions (Marsh et al., 2013; Mason et al., 2016; Moritz et al., 2011; Wölwer & Frommann, 2011).

A major factor that has confounded previous studies aimed at assessing the integrity of face encoding in schizophrenia has been the failure to control for other cognitive deficits that may have a top-down influence on task performance. Namely, most tasks that assess

one's ability to discriminate emotion expression are confounded by possible disruptions in higher-level cognitive processes. For instance, when a participant is asked to judge whether someone in a photograph is angry or afraid, the task requires not only a perceptual judgment but also the ability to make inferences or judgements about the person's mental state. Given that mental state attribution is often impaired in schizophrenia (e.g. Brüne, 2005), it is difficult to determine whether poor task performance is a result of disturbed sensory encoding or a mentalizing deficit. Also, emotion perception tasks often rely on intact working memory function, speeded decision making, and focused attention, which are all thought to be impaired in schizophrenia (Chen et al., 2009; Chen & Faraone, 2000; Conklin et al., 2005; Fioravanti et al., 2012; Forbes et al., 2009; Goldman-Rakic, 1994; Lee & Park, 2005).

A recent advance in face perception research has been the use of continuous flash suppression (CFS; Tsuchiya & Koch, 2005) to probe bottom-up perceptual mechanisms without requiring participants to make higher-order judgements that may otherwise involve secondary cognitive mechanisms (Caruana, Inkley, et al., 2019; Caruana, Stein, et al., 2019; Seymour et al., 2016). During CFS, high-contrast dynamic masks are flashed to one eye, rendering target stimuli presented to the other eye temporarily invisible. The time it takes a given stimulus to overcome this suppression and become visible to the participant is measured to index its potency in competing for awareness. Thus, shorter suppression times are thought to reflect prioritised unconscious processing during interocular suppression (e.g. Tsuchiya et al., 2009). Experiments using this technique consistently show that faces with fearful expressions gain privileged access to visual awareness over other facial expressions, consistent with reports that fear is processed by an ancient subcortical pathway dedicated to detecting threat in the environment (Capitão et al., 2014; Caruana, Inkley, et al., 2019; Stein et al., 2014; Tsuchiya et al., 2009; Yang et al., 2007; Zhan et al., 2015).

Using CFS, we have recently provided evidence for the intact pre-conscious processing of neutral face stimuli in schizophrenia. For example, patients show the previously-reported direct gaze advantage, where faces with direct gaze gain access to conscious awareness faster than faces with averted gaze (Seymour et al., 2016). Similarly, patients become aware of upright faces faster than inverted faces or non-social stimuli (Caruana, Stein, et al., 2019). Together, these findings suggest that aberrations in the evaluation of social information from faces are unlikely to result from a fundamental deficit in the preconscious sensory encoding of faces, but rather a top-down bias that influences later stages of evaluating the incoming information. However, this approach has not been rigorously applied to examine the visual encoding of emotion from faces in schizophrenia. The current study aimed to achieve this by specifically focusing on the differential prioritisation of fear and anger for two key reasons. First, the most consistent evidence of emotion processing impairments in schizophrenia come from tasks which require the evaluation of negative emotions (see Mandal et al., 1998 for a review). We chose to initially focus on these emotions to maximise our chances of detecting an impairment, if one exists. Second, we wanted to use an emotion prioritisation effect that had been established using CFS in healthy controls (Caruana, Inkley, et al., 2019). As such, in the current study, we used CFS to examine whether patients with schizophrenia demonstrate a prioritisation for processing fearful faces over angry faces. We expected any alteration in bottom-up encoding of emotions to be characterised

by longer suppression times overall, but accompanied critically by a reduced advantage for fearful faces over angry faces in order to rule out other explanations for slow reaction times (e.g. generalised attention deficits).

Method

Ethical statement

This study was approved by the Human Research Ethics Committee at Macquarie University (MQ; reference number: 5201200021). Participants received payment for their time and provided written and informed consent before participating.

Participants

Eighteen out-patients diagnosed with Schizophrenia or Schizoaffective Disorder (8M/10F) and 20 healthy controls (13M/7F) participated in this study.[1] Participants were recruited from the Belief Formation Register at Macquarie University and from the Australian Schizophrenia Research Bank (https://www.neura.edu.au/discovery-portal/asrb/). A minimum sample size of 16 per group was determined by G*Power to provide sufficient power (0.95) to detect significantly shorter suppression times for fearful faces over angry faces (based on an effect size previously observed in healthy adults; $\eta^2 = 0.488$; Caruana et al., 2020). Participants were included in the study if they had (1) no history of neurological disease or injury resulting in a concussion or being unconscious for more than one hour; (2) had no history of substance abuse (as per DSM-V criteria); (3) had at least eight years of formal education; and (4) had normal or corrected-to-normal vision. Groups did not differ significantly on age (Patients $M = 53.56$, $SD = 7.66$; Control $M = 50.80$, $SD = 11.99$; $t(36) = -0.83$, $p = 0.410$, $BF_{10} = .415$) or on premorbid intelligence (Patients $M = 106.11$, $SD = 9.15$; Control $M = 107.65$, $SD = 8.79$; $t(36) = 0.53$, $p = 0.600$, $BF_{10} = .352$) which we measured using the full-scale IQ estimate on the National Adult Reading Test (NART; Nelson & Willison, 1991). All participants were Caucasian except for two participants (one from each participant group) who identified as being of Indonesian decent.

All patients were diagnosed by a clinical psychologist or psychiatrist before being recruited into the study. The majority of patients ($n = 13$) were on a stable dose (i.e. a consistent dose for a minimum of 6 consecutive months) of atypical antipsychotic medication ($M = 253.85$, $SD = 135.34$; see Table 1 for chlorpromazine-equivalent doses). Two patients were on a stable dose of typical antipsychotic medication ($M = 100.00$, $SD = 17.68$). The remaining patients were primarily treated with stable doses of either antidepressant ($n = 2$) or anticonvulsant ($n = 1$) medication. We independently assessed participants against current DSM-V criteria using the Diagnostic Interview for Psychosis (Castle et al., 2006) and assessed symptom severity using the Scales for Assessment of Positive and Negative Symptoms (SAPS & SANS; Andreasen, 1983, 1984). All patients presented with stable and mild symptomology (see Table 1). We also used a standardised verbal comprehension task to verify Theory of Mind (ToM) impairments in our sample. Participants each read four short stories and answered brief ToM questions regarding the mental states of the characters depicted in each story. In two of the stories, participants

Table 1. Patient characteristics.

	M	*SD*	Range
Age of Diagnosis	25.06	7.53	16–36
Antipsychotic Medication Daily Dose (mg)			
Atypical ($n = 13$)	253.85	135.34	75–500
Typical ($n = 2$)	100.00	17.68	75–125
Global Ratings of Negative symptoms (SANS)	9.44	3.05	3–18
Affective flattening or blunting	1.78	1.17	0–4
Alogia	0.94	1.11	0–3
Apathy	2.67	1.14	0–4
Anhedonia	3.00	1.33	0–5
Attention	1.06	1.11	0–3
Global Ratings of Positive symptoms (SAPS)	5.94	3.95	0–12
Hallucinations	1.67	1.53	0–4
Delusions	1.89	1.37	0–4
Bizarre behaviour	0.78	1.00	0–2
Positive thought disorder	1.61	1.29	0–4

Notes: *Antipsychotic doses are provided in mg/day as chlorpromazine equivalents.
Ratings on the SAPS and SANS are provided on a 5-point scale; 0 = not present; 1 = questionable; 2 = mild; 3 = moderate; 4 = marked; 5 = severe.

were required to make First-order ToM inferences (i.e. inferences about the mental state of a character in the story). In the other two stories, correct answers required Second-order ToM inferences (i.e. inferences about what one character was thinking about the mental state of a second character in the story). For each story, participants were also asked a simple comprehension question that did not required mental state representations to control for poor performance attributable to working memory or comprehension difficulties (see Langdon et al., 2014 for a detailed task description). Patients performed poorer than controls when making second-order ToM inferences ($t(35) = 3.47$, $p_{bonf} = .020$), but did not for first-order ToM inferences or control items (all $ps > .500$),[2] consistent with the mental state attribution deficits characteristic of schizophrenia (e.g. Brüne, 2005; Langdon et al., 2002, 2014).

Healthy controls were screened using an interview protocol based on the affective, psychotic and substance abuse screening modules from the Structural Clinical Interview for Axis 1 Disorders previously outlined under DSM-IV (SCID-1; First et al., 2002).

CFS stimulus and apparatus

We employed continuous flash suppression (CFS) in order to suppresses stimuli from visual awareness (e.g. Tsuchiya & Koch, 2005) and to minimise the influence of top-down cognitive deficits on the perceptual task. Participants' heads were stabilised with a chin rest positioned 70 cm away from a Samsung SynchMaster SA950 HD LED monitor (60 × 34 cm, 120 Hz). Using a mirror stereoscope, participants viewed dichoptic displays comprising two red frames (10.4° × 10.4°) presented side-by-side on the screen. The left and right frames were only visible to the participant's left and right eye, respectively. Random noise pixels with a width of 0.5° were presented within each of the frames to facilitate binocular fusion of the dichoptic images presented to each eye. Participants were required to maintain fixation on a black fixation point (0.2°) located in the centre of the fused frame for the duration of the experiment. We also ensured that participants perceived a single (i.e. fused) frame when viewing the screen binocularly and that only one frame could be seen when viewing the screen monocularly with each eye.

We presented a set of fearful and angry face stimuli previously used in our recent studies (see Caruana, Inkley, et al., 2019 for a detailed description of stimulus properties, validation and selection). Face stimuli were presented to participants' non-dominant eye (confirmed using the near convergence test; Rice et al., 2008) as greyscale images (2° × 3°) within an oval to obscure hairlines. A dynamic mask stimulus was simultaneously presented to the dominant eye (see Figure 1). The original stimuli were taken from the Radboud Faces Database (Langner et al., 2010) but were adapted by El Zein, Wyart, et al. (2015) to equate the subjective intensity of emotion across fear and anger conditions. This intensity calibration was informed by subjective ratings obtained from a separate sample of 19 naïve healthy individuals, and verified by another sample of 10 naïve healthy individuals (El Zein, Wyart, et al., 2015). Each face identity in the original stimulus set was morphed to vary in the intensity of the emotional expression across 7 levels (for both fear and anger). However, we selected only the most extreme emotional morphs from El Zein et al. to ensure maximal discrimination during CFS and to ensure

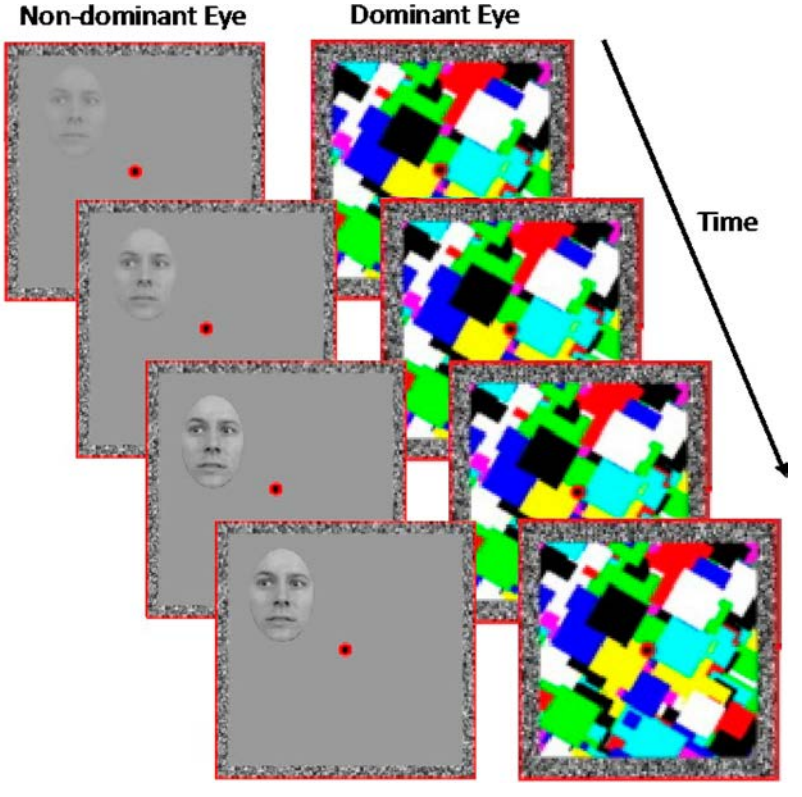

Figure 1. A schematic representation of an example trial. Masks presented to the dominant eye updated at 10 Hz, whilst an image of a fearful or angry face was presented to the non-dominant eye. For a period of time, this acted to suppress the face from conscious awareness. When the face became visible to the participant, they were required to quickly and accurately press a button to indicate whether it appeared on the left or right side of fixation. This schematic of a typical CFS trial was taken from Caruana, Inkley, et al. (2019) and is reproduced with permission from the authors in line with the article's Creative Commons licence which can be accessed here: https://creativecommons.org/licenses/by/4.0/.

emotion intensity was held constant across all conditions. Twenty-four face identities were used in the current experiment. All faces depicted young Caucasian adults. We also included two different gaze directions (direct versus averted) to account for potential influences of gaze direction on emotion perception (Adams & Kleck, 2005) and gaze biases reported in the schizophrenia literature, such as the tendency to judge averted gaze as more direct (Caruana et al., 2020; Hooker & Park, 2005; Rosse et al., 1994).

Procedure

Participants completed 384 trials (96 trials per condition) and were given a 2–5-minute break half-way through the experiment which lasted approximately 20 min in total. Trials began with the presentation of the two red frames and fusion contours and a central fixation point (see Figure 1). After 100 ms, a set of colourful, high-contrast and contour-rich masks (9.2°) were presented to the dominant eye, updating at 10 Hz. A face stimulus was simultaneously presented to the non-dominant eye, ramping up linearly in stimulus contrast from 0% to 100% over 1000 ms. The face appeared 3 degrees of visual angle from fixation in one of four quadrant locations within the fused frame. Face location was counterbalanced across conditions. The mask contrast was ramped down after eight seconds from 100% to 0% over a 2000 ms period.

As soon as any part of the image became visible, participants were required to make a keyboard response to indicate whether the face appeared to the left or right of fixation. Critically, participants were not asked to make any judgments about the face itself. They were also naive to the emotion manipulations. Together this ensured that the task minimised any higher-order cognitive evaluation of the visual stimulus. Suppression times were recorded as the time taken for participants to localise the stimulus after it had "broken through" the CFS mask (Gayet et al., 2014; Y Jiang et al., 2007; Stein, Hebart, et al., 2011). To ensure that participants were attending, we only analysed correct responses.

Results

Using CFS, we probed the integrity of early preconscious face encoding mechanisms to test for a fundamental bottom-up deficit in emotion processing in schizophrenia. In particular, we asked whether prioritised preconscious processing of fearful over angry emotional expressions–previously reported in healthy participants—is perturbed in patients.

Only trials with correct responses were analysed. Mean accuracy for localising the masked face was above 92% for all participants and no differences in accuracy were observed ($t(36) = -0.32$, $p = 0.752$) between patients [angry faces (direct, $M = 95.3\%$, $SD = 5.8\%$; averted $M = 93.3\%$, $SD = 8.2\%$), fearful faces (direct, $M = 92.9\%$, $SD = 8.5\%$; averted $M = 95.3\%$, $SD = 5.8\%$)] and healthy controls [angry faces (direct, $M = 92.0\%$, $SD = 6.6\%$; averted $M = 93.1\%$, $SD = 6.7\%$), fearful faces (direct, $M = 94.3\%$, $SD = 7.3\%$; averted $M = 94.3\%$, $SD = 6.6\%$)]. Individual trials in which the participant responded prematurely (<200 ms) or responded after the mask ramped down were excluded from the main analysis (retained trials: mean = 93.8%, $SD = 6.8\%$). There was no significant difference between patients ($M = 94.2\%$, $SD = 6.48\%$) and healthy controls ($M = 93.4\%$, $SD = 6.84\%$) regarding the proportion of valid trials retained for suppression time analysis ($t(36) = 0.37$, $p = .717$).

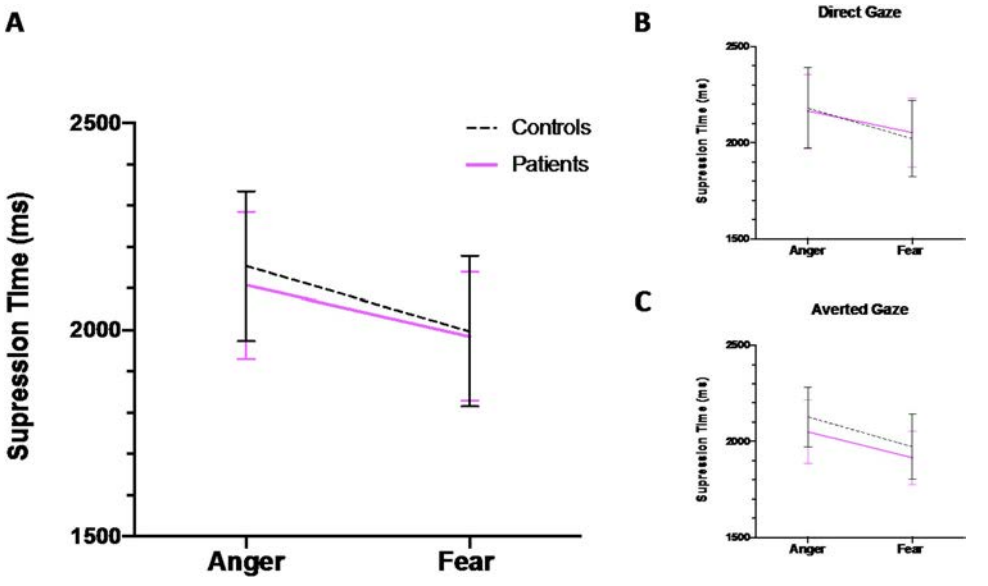

Figure 2. (A) Mean suppression time data for emotion condition and group. Overall, suppression times were significantly faster for fearful faces compared to angry faces in both groups. Panels (B) and (C) depict the mean suppression data for each gaze direction condition separately. On all figures, error bars denote 95% confidence intervals.

To account for the positive skew in reaction time data, our calculated mean suppression times were log-transformed ($\log_{10}$) for all statistical analyses (Gayet & Stein, 2017; Heyman & Moors, 2014). However, we have visualised the un-transformed data in Figure 2 below to facilitate their interpretation.

We ran a three-way mixed measures ANOVA with factors: group (patients, controls), emotion (angry, fear), and gaze direction (direct, averted). Consistent with previous CFS findings, the analysis revealed a main effect of emotion, with participants being significantly faster to detect fearful faces than angry faces ($F(1, 36) = 24.72$, $p < .001$, $\eta^2 = .032$; mean difference = 147.89 ms, $SD = 169.43$). We did not see a significant difference across groups ($F(1, 36) = .028$, $p = .869$, $\eta^2 = .001$). Both groups showed a similar prioritisation of fearful expressions over angry expressions (Patients: $F(17) = 10.17$, $p = .005$, $\eta^2 = .028$; Controls $F(19) = 14.97$, $p = .001$, $\eta^2 = .037$). Surprisingly, we did find evidence for a main effect of gaze direction, characterised by shorter suppression times for averted compared to direct gaze ($F(1, 36) = 14.62$, $p < .001$, $\eta^2 = .010$). Also, a significant group by gaze interaction ($F(1, 36) = 4.49$, $p = .041$, $\eta^2 = .003$), suggesting this effect was primarily driven by patients ($F(17) = 24.47$, $p < .001$, $\eta^2 = .026$). On average, controls did not show the effect ($F(19) = 1.197$, $p = .288$, $\eta^2 = .002$). No other interaction effects were observed between these factors of interest (all ps > .523).

Discussion

The aim of the current study was to investigate whether deficits in emotion processing in schizophrenia reflect imprecision during the initial, preconscious encoding of facial

expressions within the visual system. There is growing evidence that patients with schizophrenia exhibit low-level impairments in visual perception (e.g. Butler et al., 2008; Keane et al., 2016), however much of the research has not examined visual encoding of face-related information. Moreover, studies reporting abnormal perceptual processing of emotion from faces in schizophrenia have not used carefully designed psychophysical tasks that eliminate the potentially confounding influence of higher-order cognitive deficits. Using CFS (Tsuchiya & Koch, 2005), we probed the bottom-up sensory encoding of fearful and angry expressions, whilst eliminating the potential for face judgements to have a top-down influence on performance. Consistent with previous findings in neurotypical adults, fearful faces gained prioritised access to conscious awareness over angry faces (Capitao et al., 2014; Caruana, Inkley, et al., 2019; Oliver et al., 2015; Stein et al., 2014; Yang et al., 2007; Zhan et al., 2015). We found no evidence of a group difference with regard to this effect, suggesting that fear and anger are encoded appropriately by the visual system and that deficits in accurately recognising and discriminating these emotions in schizophrenia are therefore unlikely to be caused by a low-level bottom-up mechanism.

Previous studies that report emotion recognition difficulties in schizophrenia have typically required participants to *evaluate* the emotions expressed by faces (Bortolon et al., 2015; Kohler et al., 2010). Such tasks are unable to dissociate the role of bottom-up and top-down mechanisms, as they require participants to not only accurately encode visual information that signals emotion, but also attribute mental states to the face images. In addition, most perceptual tasks require good attentional control and working memory (Oberauer, 2019). Given that mental state attribution, attentional control, and working memory are all reported to be impaired in schizophrenia (e.g. Brüne, 2005; Langdon et al., 2014), the previous studies reporting a perceptual deficit may be confounded by a higher-order cognitive impairment. In our task, participants were not required to evaluate, compare, or remember any facial expression—they were simply asked to locate a face on a computer screen. In this way, our task removed the influence of higher-level cognitive demands that might otherwise confound perceptual judgments.

In previous research, patients have consistently demonstrated impairments in categorising or discriminating negative emotions, such as fear and anger (see Kohler et al., 2010; Mandal et al., 1998 for reviews). However, our results suggest that the preconscious registration of distinctly fearful and angry expressions is intact in schizophrenia. These results are at odds with studies that show imprecise encoding of more basic visual information in schizophrenia (e.g. Butler et al., 2008; Keane et al., 2016; King et al., 2017 for a review). Moreover, they indicate that difficulties in processing negative emotions are likely to reflect a top-down impairment involving the conscious appraisal of faces. In line with this interpretation, a recent priming study used CFS to render happy and angry face primes invisible, after which participants were required to judge the emotion of a neutral face (Kring et al., 2014). The authors showed that although patients exhibited a deficit in explicitly labelling the emotions, they demonstrated the typical and normal trend to judge neutral faces as less warm and less trustworthy when preceded by an angry face prime. This implies that the preconscious sensory encoding of emotion from faces is intact in schizophrenia, despite evidence for higher-order deficits in evaluating emotional expression.

Many studies reporting face processing deficits in schizophrenia have shown a concomitant impairment across broad aspects of social functioning (see Irani et al., 2012 for a relevant meta analysis) and on mental state attribution tasks more specifically (e.g. de Achával et al., 2010). This suggests a possible top-down influence of mental state attribution deficits on evaluating facial expressions. In support of this, previous research on the perception of other face-bound information (e.g. eye gaze) has shown that task instructions that eliminate the effects of mental state attribution demands on performance show no evidence of impaired perceptual functioning (Franck et al., 1998, 2002; Seymour et al., 2017). For example, the direct gaze bias is eliminated when participants are asked to judge whether gaze is directed to the "left or right" but the bias persists when asked to judge whether or not gaze is directed "towards or away" from the individual (Franck et al., 2002).

In the current study, we revealed that although patients exhibited characteristic mental state attribution impairments, the perceptual encoding of emotion from faces was intact. This important dissociation was made possible by implementing a carefully designed task that offered no opportunity for social-cognitive deficits to interfere with task performance. It is however important to recognise that the generalizability of these findings to all aspects of facial emotion encoding requires further empirical examination. The current study only compared fearful and angry faces. Further work examining other negative emotions (e.g. sadness), as well as positive and neutral emotions in both patients and heathy controls is needed to determine whether the early visual encoding of all emotions are intact in schizophrenia. Furthermore, the stimulus used in this study comprised faces which expressed these emotions with high intensity, thus making them highly unambiguous. Future work varying the intensity of emotional faces under CFS viewing conditions may elucidate whether the ability to encode fine differences in visual emotion information differs between patients and controls. Finally, we examined stable patients with moderate symptom severity. As such, our findings may not generalise to individuals with more severe symptoms, or those at earlier stages of illness onset (Keane et al., 2016).

An unexpected finding from this study was the effect of gaze direction on suppression times, characterised by shorter suppression times for faces with averted gaze compared to direct gaze. This trend was observed in both groups but was primarily driven by patients. This finding is inconsistent with previous research in patients and healthy adults showing a direct gaze advantage under CFS (Seymour et al., 2016; Stein, Senju, et al., 2011). We included a manipulation of gaze direction in the current study because it is known that gaze influences conscious perceptual judgements of negative emotions (e.g. Adams & Kleck, 2003; Sander et al., 2007) and that patients use gaze cues differently when processing fearful and angry faces (Caruana et al., 2020). One possibility for the surprising result is that we did not control for low-level differences in eye information conveyed by our stimuli. Specifically, we used frontal images of faces in order to maximally convey the distinct emotional expressions. As such, faces with direct gaze had an even distribution of sclera on either side of the pupil, whereas faces with averted gaze had a larger area of sclera displaced to one side of the pupil. In previous CFS studies, differences in these low-level properties have been minimised by presenting faces with deviated head orientation (i.e. turned to the left or right). Given that it has recently been reported that most effects observed under CFS can be attributed to low-level stimulus differences

(Gayet & Stein, 2017), our choice to present frontal images of faces might explain this unexpected result. However, why this was seen to be more apparent in patients is unclear and warrants further examination.

Conclusion

Our current findings suggest that difficulties in judging negative emotions (fear and anger) in schizophrenia does not reflect a fundamental bottom-up deficit associated with encoding visual information from faces. Instead, our data add to the growing evidence that emotion recognition impairments in schizophrenia are a result of top-down cognitive biases and deficits. These findings are consistent with our recent computational work which indicates that decision biases unique to patients with schizophrenia, as opposed to perceptual biases, may influence judgments of emotional expressions (Caruana et al., 2020). This distinction is important, as it will allow for appropriate intervention targets to be identified. Namely, the evidence suggests that social-cognitive remediation which targets the evaluative aspects of emotion processing may have the potential to improve social functioning in patients (Marsh et al., 2013).

Notes

1. The current sample of healthy controls were taken from a sample of 24 healthy adults used in a previous study (Caruana, Inkley, et al., 2019). However, four healthy participants under the age of 30 were not included in the current study to provide a better match between groups on age.
2. ToM data was not available for one control participant.

Acknowledgements

Thank you to Dr Marwa El Zein for kindly sharing the face stimuli that were used in this study. Thanks also goes to Christine Inkley who assisted with data collection and Dr Kelsie Boulton who assisted with clinical interviews. NC and KS designed the experiment. NC coordinated data collection. NC and KS analysed the data and wrote the manuscript.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the Australian Research Council (ARC) and the ARC Centre of Excellence for Cognition and its Disorders (CCD; www.ccd.edu.au) [grant number CE110001021]. Drs Caruana and Seymour were recipients of two ARC CCD Cross Program Support Scheme grants which directly supported this work. Dr Caruana was the recipient of a Macquarie University Research Fellowship. Dr Seymour also received financial support from the Society for Mental Health Research.

Notes on contributors

Nathan Caruana is a social neuroscientist interested in understanding the neurocognitive mechanisms that underpin social perception, cognition and interaction across our neurodiverse population.

Kiley Seymour is a cognitive neuroscientist investigating the neural basis of conscious visual perception and the brain mechanisms underlying altered states of consciousness, such as those experienced in psychosis (e.g., hallucinations and delusions).

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